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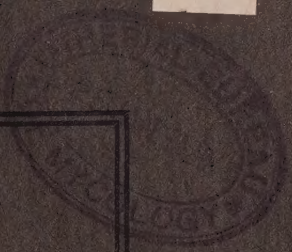

The Control of Sugar Cane Diseases.

By

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Plant Pathologist to
The Colonial Sugar Refining Company
Limited

Agricultural Report No. 6. *Sydney June 1923.*

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The Control of Sugar Cane Diseases

INTRODUCTION.

In 1907, the investigation of sugar cane diseases was undertaken in Fiji, owing to the huge losses of crops caused by the so-called "Fiji disease." It practically destroyed some thousands of acres of cane, and grave fears were entertained for a time that it might threaten the very existence of the industry.

However, certain measures were adopted, which served in four or five years to bring this and several other diseases under control so effectively, that they have caused no serious losses in the crops since.

An attempt is now being made to secure the adoption of similar measures for the control of diseases in Australia, and operations were commenced at Broadwater Mill, Richmond River in 1919, with this end in view. The results of this work will be gradually published in a series of reports, in which will also be embodied investigations made since 1907, and hitherto unpublished.

The present paper, the first of the series, deals with disease coutrol in a general way. Another, dealing with recent investigations on Leaf Scald and Gumming diseases, will follow shortly. In the case of Leaf Scald, which has not been previously investigated, a detailed account will be given of its cause and nature generally. Subsequent reports will deal with each disease separately, having special regard to their recognition and control.

The numbers following authors' names refer to the literature list attached. In order to avoid repetition of long technical names, the popular names of the

various diseases are used throughout the present paper. Reference to the table below will obviate any confusion from this course.

Popular Name.	Technical Reference.
Eye Spot	Cercospora Sacchari, van Breda.
Fiji Disease	(undet.); see Lyon (6), Reinking (9).
Gumming	Bacterium vascularum (Cobb) Grieg-Smith; see E. F. Smith (10).
Iliau	Gnomonia Iliau, Lyon.
Leaf Scald	Bacterium sp. (unpublished).
Leaf Stripe	Sclerospora Sacchari, Miy.
Mosaic	(undet.); also known as Yellow Stripe, Mottling, etc. see Lyon (6), Earle (5), Brandes (1), and their references.
Pineapple Disease	Thielaviopsis paradoxa, (de Seyn.) von Hohn.
Red Rot	Colletotrichum falcatum, Went.
Rind Disease	Melanconium Sacchari, Mass.
Ring Spot	Leptosphaeria Sacchari, van Breda.
Root Fungus Disease ?	Marasmius sp.
Root Disease	A complex of obscure diseases, as described by Earle (5).
Rust	Uromyces Kuhnii, Kruger.
Sclerotial Diseases	Sclerotium and Rhizoctonia spp. (several), on leaf-sheaths and stems.
Sereh	(undet.); see Lyon (6) and his references.
Smut	Ustilago Sacchari, Rabenh.
Top Rot	(undet.); see Tryon (11); probably distinct from types recorded elsewhere.
Beetle Borer	Rhabdocnemis obscura, Bois.
Curly Top	(undet.); occurs esp. on Northern Rivers, N.S.W., in Malabar*.
Knife Cut	*(undet.); occurs esp. at Childers, Queensland in D 1135.

*(These two peculiar affections have much in common They are not usually transmitted along with cuttings. Mites under leaf-sheaths of cane-tops, or physiological causes, have been suggested, but they are uninvestigated).

I. DISEASES AND VARIETIES.

Introduced from Other Countries.

Everyone knows that diseases take a big toll from our crops. But few realise that we probably have a longer list of serious maladies attacking our cane than any other country with correspondingly high losses regularly recurring.

This unenviable position has arisen from the wholesale unrestricted importation of varieties from abroad, followed by the free interchange of them amongst the various cane growing districts in Australia. The fact is that Australians have, for upwards of fifty years, persistently sought for new and improved varieties, some thousands of which have been imported from Mauritius, New Guinea, West Indies, Hawaii, Java, India, Louisiana and elsewhere. No other country has apparently done so much in this direction.

The weak feature of this progressive policy has been that it has not been accompanied by rigid precautionary measures against the introduction of diseases and pests along with the cane plants. The result is that Australia now harbours a majority of the diseases known in other sugar-growing countries, and, in addition, an equally formidable array peculiar to ourselves. The latter come mainly from New Guinea, where sugar cane is not grown commercially, and hence little about diseases has been recorded.

Thus, such diseases as Gumming, Mosaic, Red Rot, and true Rust are considered to have been introduced in cuttings at an early date, before any New Guinea canes arrived here. Of these Mosaic and Red Rot occur in nearly all sugar-growing countries, and Rust in many, while Gumming is considered by Deerr (3) to have occurred long ago in Brazil and Mauritius, whence it probably came to us.

Fiji disease, Leaf Stripe (Sclerospora) and Leaf Scald were known in no other countries until of quite recent years, and are therefore suspected of being importations from New Guinea. Definite evidence that this is the case regarding Fiji disease has been published by Lyon (6), who also suggests Australia or Fiji as the most likely origin of the disease in the

Philippines, where its presence has been recently discovered. But similar evidence regarding Leaf Stripe and Leaf Scald is still to be obtained. A severe epidemic in Formosa, however, was caused by Leaf Stripe, and its origin there was definitely traced to varieties sent from Mackay, Queensland, in 1909. Then in 1920 this disease also reached the Philippines in cuttings from Formosa. These successive migrations have been fully dealt with by Weston (12), whose interesting paper will again be referred to.

The above examples include the better known of our serious diseases. In addition, our crops have, from time to time, been severely affected by Top Rot, Curly Top, Knife Cut, various root diseases and certain leaf diseases, the investigation of none of which has yet been seriously undertaken. A whole host of minor diseases also occur, of which many potentially are destructive diseases, although not having yet proved particularly so with us. These include a variety of leaf-spots, and leaf-sheath, stem and root fungi. The great majority of these have, beyond doubt, also been introduced with cuttings from abroad, largely from New Guinea. Although, probably, a few will eventually be found to have transferred their attacks to sugar cane from other plants, it is noteworthy that not a single one is yet considered to be endemic.

Notable examples in other countries, which are not yet known to have reached us, include Sereh of Java, Iliau of Hawaii, and the cane Smut of several countries. Thus we still have occasion to fear importation of further troubles from abroad. And in this connection, it would appear that importations from New Guinea are again to be regarded as the most dangerous of all, as they have proved to be in the past; because, the canes being grown there under the most primitive conditions, entirely unknown diseases and pests are likely to occur amongst them. And just as the parts hitherto unexplored for this purpose, such as the late German territories, may be expected to yield the richest harvest of new and valuable varieties, so may they be expected to yield most in the way of new and terrible diseases and pests.

While it is not proposed to deal with the subject of insect pests, it should be pointed out that many of

them are just as liable to be carried with cane plants as diseases, that important ones have thus been introduced from other countries and distributed within Australia, and that when once established they may prove even more difficult to control than diseases. In fact, most of the remarks made here regarding varieties and diseases would apply with equal force to insect pests.

The case of the well known Beetle Borer (Rhabdocnemis obscure Bois.) alone will sufficiently illustrate this contention. Long before it reached Australia, it was well known in the Hawaiian Islands, to which, according to Muir and Swezey (8), it was probably introduced about 1854 from the Southern Pacific, along with varieties of cane. Its original habitat was probably New Guinea and the adjoining islands. "Australia," they say, "got it from New Guinea in shipments of seed cane. As its presence has actually been detected in the more recent importations from there, made by the C.S.R. Co., Ltd., the probability is that it has arrived with each successive batch of New Guinea canes. They also say "Seed cane sent from Honolulu to Formosa, although inspected before being shipped, and again upon arrival in Formosa, was suspected to be infected after it was planted. It was therefore dug up and grubs were found in several pieces of cane." Thus the difficulty of detecting the presence of its eggs in cane plants is shown.

Fiji has not been counted as a country distinct from Australia in the above discussion, because its crops have been affected by practically the same list of diseases as those of Australia. The free interchange of varieties maintained for a long time between the two countries has brought this about. Thus in the matter of diseases and varieties Fiji has been more in the position of a part of Australia, then in that of a distinct country.

DISTRIBUTION WITHIN AUSTRALIA.

Interchange of varieties has naturally been carried on more freely within Australia than between it and foreign countries, and generally speaking, the easier the transport facilities, the more often have varieties been exchanged. But the Government Ex-

periment Stations and other institutions, the various mill authorities, private cane farmers, even dairy farmers and other private individuals only remotely interested in sugar cane, have all been so active in the matter, that practically every variety of any promise has been introduced to each mill district. Many conspicuous varieties have reached the same district over and over again.

In all this, there has been an entire absence of restrictions or precautionary measures of any kind as far as private individuals are concerned—except that the appearance of badly diseased canes does not naturally recommend them for use as plants—and such precautions as have been voluntarily taken by the various institutions and mill officials, also have frequently been quite inadequate. That almost every disease must have been introduced to every district is therefore to be expected. Generally speaking, this is found to have been the case, but some most surprising exceptions to this rule have been noted.

Thus, it is most difficult to explain why Fiji disease has never become established at any of the C.S.R. Co.'s Queensland mills, while it has been for so long prevalent and highly destructive at the three N.S.W. mills and in Fiji; why Leaf Stripe disease has not been found in N.S.W. or the Childers district, while prevalent at Mackay and all the districts north thereof, and in Fiji; or why the beetle borer has not reached districts south of Mackay (all these remarks referring solely to the C.S.R. Co.'s mills, of which alone data are to hand.) Similar examples, applying to distribution in much more restricted areas, might also readily be given. Although, in each of these cases, the disease concerned has, likely enough, been several times introduced with cane plants and yet failed to become established, it certainly cannot be claimed that the conditions are such that it could never gain a foothold and become a serious factor in the districts in question. But these examples chiefly serve to illustrate the capricious nature of diseases in such cases, how sometimes they fail to establish themselves in spite of being given a good chance to do so, while a t other times they may creep in through the tiniest loophole.

The present distribution of diseases also depends on another important factor. In several districts diseases which once caused severe epidemics, have since completely disappeared. Having first been successfully controlled, mainly by the use of resistant varieties, they subsequently appear to have been completely eradicated.

Thus Gumming, which at one period or another has devastated the crops of nearly every mill, has now apparently disappeared completely from Harwood and Condong mills, also from Lautoka, Rarawai, Nausori, and Labasa mills, in Fiji, it not having been heard of at any of these for a number of years. On the other hand, it is again approaching epidemic proportions at Broadwater, Victoria, and Macknade mills; there are signs of a slight recrudescence at Childers, and it has lately been heard of in small areas at other centres. Similar instances with other diseases might also be quoted.

In spite of the well known difficulty of proving that any living form has become extinct in a given place, and the oft proved liability of diseases to remain hidden away in some obscure latent condition, after apparent eradication, to await the return of conditions favourable to their fresh development, it still seems likely, in some of these instances at least, that complete extinction has actually taken place. The present virulent outbreak of Gumming at Broadwater, for example, would appear to rule out the idea that conditions at Harwood and Condong are merely unfavourable to its development, either as regards varieties, soil or weather. In fact, the reintroduction of Gumming to the two latter mills, which lie close on either side of the former, is greatly to be feared, owing to the frequent interchange of varieties by farmers, which takes place between them.

These and numerous similar considerations clearly show the great need that exists for the establishment of some form of control over the movement of cane plants within Australia, to guard each district against both the introduction of new diseases from other districts, and the reintroduction of old ones, which have been brought under control.

RESISTANT VARIETIES AND DISEASE CONTROL

A large measure of success has undoubtedly been obtained in the control of diseases by means of resistant varieties. But far too much stress has been laid on this feature, just as if resistant varieties provided the one and only means of combating diseases at our disposal. The variety has been blamed whenever crops have become diseased, and another sought to replace the diseased one. Thus varieties have come to be chosen primarily for disease resistance. Those giving the highest tonnages and sweetness, on becoming diseased, have frequently been replaced by inferior ones as regards yield and quality, when the disease might have been more profitably controlled by other means.

With the new varieties came new diseases, each variety being sooner or later attacked in its turn, either by a new disease or an old one resuscitated. Thus a vicious circle was established, new diseases having called for new varieties, which brought more diseases and more varieties, and so on, until we now have, as already explained, nearly all the serious maladies known in other countries, and as many more peculiar to ourselves. Another unfortunate circumstance is the fact that, while the varieties are easily discarded (not one-twentieth of those introduced being still preserved for our use), many of the diseases they brought came to stay, defying our efforts to eradicate them.

In fact, frequent change of variety has become quite a fetish amongst farmers. It is a popular belief that a variety degenerates or "runs out" after long years of cropping. The appearance of disease is generally regarded as evidence of this "running out," even though the variety in question may have only been in use for some five or ten years. While the idea that long continued asexual (i.e. vegetative) propagation may ultimately lead to senility and consequent degeneration, is rational enough in an abstract way, it is scarcely conceivable that senility could be reached in the short space of 10 or 12 years with such a long lived plant as sugar cane. As a matter of fact, numerous examples may readily be quoted, in which varieties have been propagated vegetatively for much longer periods, without signs of degeneration becoming a general feature.

Lahaina, for instance, which is still the chief variety of the irrigated plantations of the Hawaiian Islands, has been grown there since 1854 (68 years). Deerr (3) traces it back to 1766-68, when it was introduced from Otaheite to Mauritius and Bourbon. It has therefore been continuously propagated vegetatively (from cuttings) for over 150 years, and how much longer history does not relate. During that time it has been the standard variety of many countries, under many different names, such as Otaheite, Bourbon, Louzier, White Bamboo; as Honolulu in parts of Australia and Fiji. It has always proved susceptible to diseases, and has been associated with many of the great historic disease epidemics of the past. For many of these, as Deerr (3) points out, the degeneration of the variety was assigned as the cause. Yet a healthy, vigorous stock of it has been maintained to the present day in the Hawaiian Islands. Degeneration as the result of age, therefore, appears an ill-founded explanation; the true cause of the "running out" in each case was to be found in the attack of a virulent disease-producing organism. This means that elimination of the organism from the districts affected, and the use of a healthy stock for seed, would always enable a desirable variety, which had been discarded, to be again reverted to as the standard cane. As a matter of fact, this actually took place with the variety in question, which, Deerr (3) shows, was the standard cane in Mauritius from 1768 to 1848 under the name of Otaheite, and again from 1870 to 1900 as Louzier. Similarly Badila was thought to have "run out" in Fiji, when it became so badly affected by Fiji disease, but in this case the disease has been brought under control without discarding Badila or finding a more resistant variety.

This continuous hunt for disease-proof varieties might be justifiable if there were a likelihood of finding any which are immune, or even highly resistant to all diseases. But amongst all the thousands that have been tried, no universally immune cane has been discovered. Nor is there any prospect of obtaining such an ideal variety, because this would be contrary to all experience in nature, every living organism being subject to its own peculiar ills. Badila appears to be the nearest approach found. That it owes its pre-eminence over other varieties in Australia far more to

its high powers of resisting diseases than to its superior quality and yielding capacity must be conceded. For, it has replaced many varieties which became diseased, although beforehand they were considered superior to it in yielding capacity. For example, B 208 on the Herbert River was discarded on account of Leaf Stripe, although it was considered superior to Badila in other respects. HQ 426 (Clark's seedling) on the Herbert River, is now being restricted in favour of Badila on account of Gumming. Every farmer will readily call to mind similar instances of highly superior varieties, which he has discontinued planting on account of some disease or other. Yet Badila is far from being universally immune, as it was badly damaged by Fiji disease in Fiji, it is now proving too susceptible to Gumming for planting in certain areas at Broadwater, and it is somewhat subject to Mosaic, Leaf Stripe, and Leaf Scald diseases. Nevertheless. it is amongst the most highly resistant of our varieties to each of these diseases.

"New," methods of controlling diseases, in addition to the use of resistant varieties, are therefore ugently needed in Australia. The methods of control now to be suggested, if thoroughly carried out, would, it is believed, gradually reduce losses. They should, in the course of a few years, bring our most important diseases practically under control, as has already been done in Fiji. These measures need entail little additional cost beyond the exercise of more care. They have the further aim of allowing better use to be made of varieties. Instead of choosing them mainly for disease resistance, as at present, we should later be able to choose them primarily for their high quality and yielding capacity, relegating disease resistance to the subsidiary position it deserves.

The problem in Australia, however, is one of greater magnitude than that in Fiji. Its successful solution will take longer, and will depend entirely upon the whole-hearted co-operation of all those concerned. Little progress is to be expected until such co-operation is secured, both by general agreement, and by the enactment of suitable quarantine regulations. And while in Fiji general co-operation was readily obtained, it promises to be quite otherwise in Australia, owing to the diversity of interests involved, and to the large number of independent cane-growers concerned.

II. THE NATURE OF OUR DISEASES, AND THE MEANS FOR THEIR CONTROL.

Before discussing disease control generally, it should be pointed out that each disease requires a different treatment specially adapted to its peculiar nature, and that control measures need to be based on an intimate knowledge of each particular disease.

But as our more important diseases have all been imported along with cane plants, as already explained, it naturally follows that they all resemble each other in their liability to be transported and propagated by the use of infected cuttings. They are also similar in that varieties show varying degrees of susceptibility to them. There are, however, marked differences regarding the particular varieties which are susceptible to each, a variety which is highly susceptible to one disease frequently proving one of the most resistant to another. In regard to certain other characters of high importance for control purposes, the diseases may be arbitrarily grouped into three types, as follows:—

Type 1.—Gumming, Leaf Scald, Leaf Stripe, Fiji disease and Mosaic resemble each other in that a diseased set will always produce a diseased plant. This is the case no matter how lightly infected the original set may be. For, in practice, it is found that stools, which to all outward appearances are perfectly healthy, may yet sometimes be infected, and thus yield cuttings which will produce diseased plants. Transport of the cuttings to far distant countries will not even influence this result.

Each one also is highly infectious, that is to say it may spread from diseased plants to any healthy ones grown within range of infection.

In each case, these characteristics depend on the disease being caused by a particular microscopic organism. Each organism is a strict parasite. It cannot thrive for long apart from its living host, the sugar cane (except that certain allied plants may, in rare cases, also serve as alternative hosts). But it lives and multiplies in cane so persistently that it can practically never be got rid of. Cane once infected is permanently diseased, that is, these diseases are incurable. Infection depends on the organism being provided with means of transport from diseased to

healthy plants, when it must also have some method of entering the living tissues of the latter.

Undoubtedly, diseased stools of cane provide the main source for the infection of healthy cane. Alternative hosts may be of importance in certain localities, but serious trouble from this source has not yet been traced. And, although evidence of infection resulting from any of these organisms living and multiplying in the soil, apart from living cane, has been constantly looked for, none has been found. It is now safe to say that soil infection does not, at any rate, constitute a serious factor in the propagation of these diseases. Little is known about the vehicles by means of which the organisms travel from diseased to healthy plants. This question will be discussed in a later section.

Effective measures for controlling these diseases may be founded on the characters just described. Although incurable, they are still preventible by measures variously referred to as "Clean Cultivation" or "Field Sanitation."

First, seed selection is required, the aim being to avoid the planting of any diseased sets. While the planting of an odd infected set here and there may be regarded lightly when the planting is done in an infected locality, it is a serious matter in any area where the disease in question does not occur. Similarly, the transport of even one infected set to a distant district would be a more serious matter still, as it might ultimately serve for the infection of a huge area, possibly to spread the disease throughout the whole district concerned.

Success in seed selection depends on an accurate knowledge of the critical symptoms of each disease, especially of those which serve for their diagnosis in the early, most difficult stages, when affected canes show least change from a normal healthy condition. As Lyon (6) says, "These defensive measures are efficacious in exact proportion to the ability of those directing them to distinguish these diseases in all of their various phases."

Further, as canes may be diseased even though they appear perfectly healthy, it becomes necessary to avoid for seed purposes fields in which infection may reasonably be suspected, even though no diseased canes can be detected in them. This is the case with

all five of the diseases named, but in varying degrees. With Gumming and Leaf Scald, it is of the highest importance in all cases, even in ordinary field practice. Whereas with Mosaic, it needs to be considered only in the case of plants to be forwarded to distant places. In addition to a knowledge of the critical symptoms, this kind of seed selection also requires an intimate knowledge of the nature of each disease, of the manner in which infection spreads, the distance it may travel, and many similar factors. For example, much use has been made of the knowledge that Fiji disease thrives especially on rich land, Leaf Stripe on poor land, Gumming in badly drained areas, Leaf Scald on higher dry land, and Mosaic in hilly country.

Much of the knowledge thus required may be gained from a study of the literature named in the attached list and similar papers. To supply such information will also be the main object of the subsequent papers of the present series already referred to.

Next, with the object of removing sources of infection, badly diseased fields should be ploughed out after harvesting, and odd diseased stools in other fields should be eradicated. Seeing that diseased stools provide the main, if not the sole source of infection for healthy canes, their systematic destruction, combined with seed selection, if thoroughly carried out, would alone suffice to stamp out these diseases completely. Such drastic measures, however, become impracticable where a disease has become widespread. Take for example the extreme case in which all the cane of a whole farm has become infected, and this, unfortunately, is by no means uncommon. In such a case, the farmer cannot be asked to plough out his whole farm at one time. For he must live.

Where a disease is highly prevalent, therefore, slower, more or less partial measures have to be adopted. It is in these cases that the use of resistant varieties becomes of enormous value, as an adjunct to seed selection and eradication, carried out as far as practicable.

Many other precautions become desirable in special cases, such as the avoidance of knife infection with Gumming and Leaf Scald, improvement of drainage, and improvement of cultivation methods generally. But these are beyond the scope of the present paper.

These five diseases comprise the most virulent ones we have to deal with. Attention has therefore been hitherto focussed on their control.

Type 2.—Red Rot, Root Fungus disease (Marasmius type), and the Sclerotial diseases of the leaf sheaths will serve as examples of a large group of important diseases caused by weak facultative parasites. They can only attack cane in a more or less enfeebled or damaged condition. But they largely live on decaying cane and other vegetable matter in or on the soil, where they may persist for long periods without live cane. When cane is planted in such soils, it may become more or less severely affected in unfavourable seasons, especially in drought periods. Or, the attacks of these parasites may be favoured by floods, wind damage, poor soil, pests, other diseases, in fact any cause of weakened vitality of the cane. On the other hand, under sufficiently favourable conditions, the cane in such soils may grow in a healthy manner and be immune to their attacks.

Diseased sets may serve to disseminate these diseases either from field to field or from one country to another. But, while an infected set will usually produce an infected plant, the diseases are not incurable, in the sense applied to those of Type 1, as at times healthy plants may even be propagated from infected sets. Also, while infection may spread from diseased to healthy plants, this is far from being the sole source of infection, as already indicated.

For controlling these diseases, therefore, in localities where the parasites are already prevalent, seed selection and the eradication of diseased plants are only of secondary importance. Chief reliance must be placed on reducing the amount of infection from the soil, by judicious rotation of crops and the use of resistant varieties; also on promoting a thrifty even growth, which will aid the crops in resisting infection. The latter is mainly a matter of good cultivation, manuring, drainage, in fact any measures aimed at overcoming adverse conditions of climate, soil, etc., in which choice of variety also plays an important part.

When, however, plants are to be brought from another country or another district, to one in which a particular disease of this type does not exist, the selection of plants absolutely free from infection is just as important with this as with diseases of Type I.

Top Rot, an Australian disease of high importance may be provisionally added to this type, pending detailed investigation. Also such common affections as Rind disease and Pineapple disease should possibly be included. But the latter are still feebler parasites, if indeed they may be classed as parasites at all; for apparently they only attack parts which are already in a more or less dying condition from other causes.

Type 3.—A great variety of leaf spots, such as true Rust, Eye Spot and Ring Spot, may be grouped together as a third type of disease. The majority of these, although of conspicuous appearance, are not usually sufficiently harmful to warrant special control measures. They mostly appear at a particular season, frequently in winter, and disappear again after a longer or shorter period, leaving the cane little the worse for the attack.

But occasionally particular varieties have been so severely attacked as to be badly damaged, even killed outright, by certain of these diseases. In such cases the varieties affected have had to be discarded, and more resistant ones substituted.

The introduction of such a disease to a new district, in which the standard variety happened to be a susceptible one, is therefore liable to be followed by disastrous results, and needs to be strictly guarded against, as the occasional severe outbreaks of so-called "Rust" in the past clearly show.

The causative organisms of some of these diseases are strict parasites, while those of others belong to the weaker facultative class.

But it needs to be emphasised that by no means all leaf spots and streaks belong to this comparatively mild type of diseases, especially as it is customary in Australia to refer loosely to all such spots collectively as "Rust." For each of the five destructive diseases of Type I produces its own particular leaf markings, which to the uninitiated are also merely "Rust." Yet these markings provide the best available means for the recognition of these diseases in their early stages. Red Rot and Top Rot (of Type 2) similarly produce their own characteristic "Rust" in the leaves. Accurate differentiation between the various "Rusts" so-called, combined with a knowledge of the significance of each is therefore of prime importance in disease control work.

PART II.

III. THE VARIETY QUESTION.

Safeguards Needed Against Distribution of Diseases with Cane Plants.

This important question is of such a contentious nature that it would be presumptuous to formulate a definite plan to deal with it at the present time. However, an outline of the plan now favoured by the writer, and endorsed by the C.S.R. Co., is tentatively submitted, as a basis for the discussion which follows it. The safeguards suggested are that:—

1. Every precaution practicable should be taken at the forwarding end, to ensure that perfectly healthy plants are alone selected for distribution.

2. (a) Every imported cane should be grown in strict quarantine, until its freedom from diseases and pests is assured. Foreign importations should be strictly limited to a few varieties now and then, say, not more than three at a time, at intervals of a few years. None but varieties of quite outstanding promise should be imported at all.

(b) No cane plants should be sent from State to State, nor from mill to mill within Australia, except under strict pathological supervision. Such plants would usually need to be detained and grown in quarantine for one or two years en route. Quarantine might be waived only in the case of neighbouring mills, where similar conditions obtain, the same standard varieties are grown, the same diseases occur, and in all other respects there appears but slight risk of introducing a disease not already present.

(c) Within a particular mill district the question becomes a local one of "seed selection." Transportation of plants in bulk should generally be discouraged. It, however, becomes necessary at times, for controlling a particular disease. Technical supervision should be exercised as far as practicable over all exchanges of plants. And, generally speaking, the more widely separated the districts, the greater the risk will be, and the greater the need for supervision.

3. New varieties should be obtained by raising seedlings, rather than by importation from abroad. Seedling raising should be undertaken at a number of different centres. Only the few seedlings of highest

promise should be exchanged with other centres, when the same precautions should be observed with them as with ordinary varieties. For seedling raising purposes, the aim should be to maintain a healthy stock of all present varieties regarded of promise as parents.

The above plan is intended to meet the difficult conditions at present obtaining. Modification may be required, when fresh facts are brought to light by further investigations. Also, the risks attending the exchange of varieties between different mill districts would be greatly reduced, if the diseases in Australia were to be controlled to the extent already accomplished in Fiji.

Admittedly, it involves rather drastic changes from the system at present in vogue. This applies particularly to part 2, which, in our opinion, represents the minimum amount of restriction on the movements of cane plants that the case now demands. But the exclusion of all foreign canes, at least temporarily, is also worthy of consideration. Some measure of general agreement should, however, be reached before definite new quarantine regulations for enactment are framed to meet the case.

The difficulty of the position lies in the fact that we are torn between the following two conflicting considerations:—

On the one hand, there is the great value of obtaining new and improved varieties. Resistant varieties are required for combating diseases. Substantial gains may also be looked for from the higher tonnage and sweetness yielded by superior new varieties. As all are agreed on this point it need not be further enlarged upon.

On the other hand, many unfortunate occurrences show the impossibility of guaranteeing the freedom from disease of cane plants selected for forwarding elsewhere. Even selection with the greatest care combined with the highest technical skill, has sometimes failed, so effectively are some of the worst diseases liable to be concealed in plants. Further, it has proved equally unsafe to rely on additional precautions at the receiving end, where the varieties are planted, so rapidly and mysteriously do such diseases sometimes spread.

Fortunately we have in seedling raising, an alternative means of obtaining new varieties without any of the dangers attending importations. This is the very essence of the plan proposed. More and better varieties than ever may well be expected from properly conducted seedling raising alone.

WHY CANE CUTTINGS CANNOT USUALLY BE GUARANTEED FREE FROM DISEASE.

The huge extent to which diseases have been imported into Australia, and distributed within Australia, in cane cuttings, has already been explained. Much of it may be credited to carelessness or ignorance on the part of those selecting the plants distributed, and might, no doubt, have been avoidable.

But even when every precaution known to science has apparently been taken to secure healthy plants, diseases have sometimes been carried. Some most costly accidents of this nature have occurred, when the whole business has been in the hands of big experiment stations and controlled by competent plant pathologists. Such of these occurrences as have been traced out and published, have been taken account of in the framing of quarantine regulations. These, in certain advanced countries, notably the United States and the Hawaiian Islands, go so far as to prohibit the importation of foreign canes absolutely.

For example, Mosaic disease now occurs in nearly all sugar-growing countries, and in several of these, the activities of the experiment stations have been mainly responsible either for its importation from abroad, or its wide distribution in the country concerned, or both. This has been due to failure to recognise, for a considerable period, that the affected canes had anything wrong with them. In Louisiana, for instance, Brandes (1) furnishes striking evidence that the disease was introduced prior to 1913, and became well established at the Sugar Experiment Station about 1914, since when "every point receiving seed from the station has become the center of a larger or smaller infected area." Yet the presence of the disease was not discovered there until July 1919, when he recorded that "about 97 per cent. of the cane plants at the station have the Mosaic disease." He also points out that "There is no known method by which the presence of the disease in cuttings can be

positively established"; but that "such an importation would be practically impossible with the present quarantine against sugar cane."

Further, it has been proved in the case of Leaf Stripe, Fiji disease, Gumming, and Leaf Scald, that the disease may for a long time remain latent in growing cane, or at least so obscure that it cannot be detected by any known means. In such cases, the cane appears perfectly healthy, and is therefore liable to be selected for use as plants.

This is exactly what happened when Leaf Stripe reached the Philippines early in 1920 from Formosa. Weston (12) shows that the cane plants were grown at the Government Experiment Station in Formosa, "where they had been dealing with the disease since 1910, and would be best qualified to select healthy cuttings"; that the cuttings were dipped in Bordeaux Mixture; that after planting in the Philippines, the canes were periodically inspected for Leaf Stripe disease by competent pathologists; but that "it was not until April 1921, the cane having been ratooned, that numerous cases of etiolation of the young plants were observed." Thus the disease remained latent and did not appear until the canes had been growing for over a year, and had been ratooned.

A similar experience with Fiji disease was provided by the introduction of seedling varieties from Rarawai mill, Fiji, to three Australian mills in 1908 and 1909. The cuttings were carefully selected by the writer from stools in which no symptoms of this disease could be detected, the usual treatment with Bordeaux mixture also being applied before shipment. Certain of these stools at Rarawai, as well as the cuttings from them in Australia, did not develop the symptoms until over 8 months after the cuttings left Rarawai. Yet it is certain that the cuttings carried the disease, which must therefore have remained latent for that period, because no other Fiji disease existed at Macknade and Childers mills, where part of them were planted. Further, timely destruction of the diseased plants thus produced, fortunately served again to rid these districts of this disease. In the third district (Harwood mill) this reasoning did not apply so forcibly, because Fiji disease was already prevalent there before the varieties were introduced.

Numerous other experiences could similarly be quoted to show the great danger of each of the four diseases named being carried in cuttings, in this latent unrecognisable condition. In fact, this feature proves one of the greatest obstacles of all to the successful control of Gumming and Leaf Scald, as will be explained in a later section.

Therefore, whenever cane plants are forwarded elsewhere from any district where diseases of this nature occur, or may be suspected of occurring, it becomes necessary to pass the plants through a strict quarantine system before planting them at the receiving end.

WHAT CONSTITUTES AN EFFECTIVE QUARANTINE FOR CANE PLANTS?

The usual practice in this country is to plant newly introduced varieties at one corner of a cane field, or in one's back garden, or at any convenient spot, this being rarely more than a quarter of a mile distant from other growing cane. Where care is exercised, the young plants may then be kept under close observation during their growth, and any which develop suspicious symptoms at any stage, may be promptly destroyed.

While such rough and ready precautions as these are of undoubted value, they are liable to prove quite inadequate in cases like those quoted above. This is especially so, because the diseases are sometimes highly infectious even while still in the latent unrecognisable condition referred to. For quarantine purposes the introduced cuttings should be planted well isolated from ordinary cane fields, at the least out of reach by flying insects, by which many plant diseases are known to be disseminated. The same precaution is needed against insect pests, which may be harboured by the plants.

Unfortunately, little is yet known about the means by which the infection of cane diseases is actually carried. Brandes (2) shows that Mosaic may be transmitted from diseased to healthy cane by certain leaf-sucking insects of the aphis and leaf-hopper types. Miyake (7) has found that the spores of the fungus which causes Leaf Stripe, are carried by wind. The writer, in a later paper, will show that both Gumming and Leaf Scald may be transmitted by

the knives of cane cutters. But field observations clearly indicate that some of these diseases also have other more efficient means of transmission than these. The rapidity of their spreading, and the long distance that infection is often carried could not otherwise be accounted for.

A quarantine, to be effective, must also aim at excluding unknown diseases, especially when importations from such a country as New Guinea are contemplated. Every means known to science, by which any plant diseases may be carried, should therefore be considered, and very formidable barriers indeed should be arranged for the isolation plots. Such barriers may be provided by an island separated from the mainland by several miles of sea, or by a big mountain range, or by localities widely separated by distance from cane growing areas. Isolation in specially constructed, insect-proof green-houses is also a method commonly used.

The isolation thus suggested, while it may not entirely eliminate every conceivable means of infection, should serve to reduce the risks in practice to a negligible minimum, provided that it be properly supplemented by further precautions. The nature of these precautions may be gathered from the following example:—

A convenient quarantine system is now being used by the C.S.R. Co. for the introduction of a few varieties from Fiji and New Guinea. Instead of sending the cane plants direct to a sugar-growing district. they are planted in carefully chosen places near Sydney, in gardens attached to private residences, the occupants of which look after the plants during growth. Although so far south of the tropical cane areas, it is found that satisfactory growth may be obtained in the warm sandy soils of the frost-free coastal districts, with the aid of hand watering and a little stable manure. Periodical inspections for the presence of diseases and pests are facilitated by proximity to the Company's Sydney offices. The details aimed at are as follows:—

1. Only a few cuttings (one to four) of each variety should be introduced.

2. The cuttings of not more than three varieties should be planted in one isolation plot.

3. Isolation plots should be separated from each other by at least a mile.

4. In each plot, every plant should be periodically (at least once a month) examined by a trained observer for the presence of diseases and pests.

5. Prompt measures should be taken to eradicate any diseases or pests found. Even suspicious symptoms warrant the destruction of the plants showing them. Usually it will be sufficient to destroy the individual stools showing symptoms, but whether single stools, or only parts of stools, or all the stools of the plot should be destroyed, would be determined by the nature of the affection. Should any disease like Gumming, or any of the troubles collectively termed "Root disease" (see later) be detected, the whole plot containing it should be immediately destroyed. In rare cases, even plots a mile or so away might be involved as well.

6. The duration of a safe quarantine period is difficult to determine. For the present, a period of two years is regarded as the minimum. If during that time the plants make normal thrifty growth, and adequate inspections fail to detect any suspicious symptoms, the risk on forwarding the cuttings to sugar-growing districts should be practically negligible.

But any damage by frost, drought, domestic animals, rats, and the like, would increase the risk by interfering with the detection of diseases, and would necessitate a lengthening of the period. And, as disease in any one stool exposes the whole plot to infection, the quarantine period of each whole plot should date from the destruction of the last diseased stool in it.

7. Any knife or other implement used on a diseased plant should be sterilised before further use. This is especially necessary when proceeding from one plot to another. Numerous other possible means of infection may be imagined, against which appropriate precautions are needed, but the danger from them will be small in such carefully guarded plots as these. Probably the chief danger of this kind, is the liability of those attending the plants, or curious visitors, to carry infection unconsciously on their implements or clothes.

Also a few private individuals grow sugar cane for amusement. Any such plants need to be sought out, and either destroyed, or controlled as if they also were isolation plots, or else the isolation plots arranged must be situated far distant from them. If sugar cane should thus become common in Sydney gardens, this system of quarantine could no longer be entertained. In that event, the use of the green-house system would be favoured instead.

And certain insect pests and fungus parasites of other plants are liable to transfer their attention to the plots of sugar cane in a mild way, and cause complications. But no trouble from this source has been experienced during the past two years.

The small number of plants specified facilitates thorough examination, and reduces the risk of diseased plants being overlooked. The small plots are used, because one diseased plant may often involve destruction of the whole plot. From this point of view, an isolation plot for each individual plant would be ideal; but the arrangement would unduly multiply the number of plots, and be otherwise inconvenient.

WHY IMPORTATIONS OF VARIETIES SHOULD BE RESTRICTED

to the small proportions proposed, should now be clear. In any quarantine system adopted, the most difficult diseases to contend with, will be the inconspicuous ones which may defy detection for long periods, as Mosaic did in several countries in the manner already noted. Mosaic can, of course, be readily detected now, but "new" diseases similarly obscure are still to be feared. For example, Earle (4) gives strong grounds for suspecting the presence of a whole series of root affections, about the detection of which so little is yet known that one cannot be distinguished from another, but all are termed collectively "Root Disease." Yet he states that they constitute "by far the most serious problem that confronts the cane growers ..... in all parts of the sugar-cane growing world."

Obviously no quarantine system can afford us complete protection against such obscure diseases as these. But it would still seem that the risk of canes harbouring a dangerous affection would be small, after having grown for two years in quarantine in a normal,

vigorous manner, without showing any signs of it during that period.

This line of reasoning, however, shows the need for strictly limiting importations to varieties of outstanding promise. The risks involved are the price to be paid, only when a big prize is offering. Should even one disease, another "Gumming" for example, manage to evade our vigilance, the price might indeed be large. It is clearly a matter for the whole sugar community, not for individuals.

RELATIVE MERIT OF SEEDLING RAISING VERSUS IMPORTATIONS FOR OBTAINING NEW VARIETIES.

Seedling raising has not been much exploited in Australia. The HQ series raised by the C.S.R. Co. at Hambledon mill, Cairns, and the Q series raised by the Queensland Aclimatisation Society at Brisbane, between 1901 and 1907, comprising about 2500 seedlings in all, constitute the only considerable attempts made. These yielded some useful varieties, including HQ 426 (Clark's Seedling), HQ 5, HQ77, HQ409, Q116, Q813, Q970, and Q1098. Then a fresh start was made in 1921 at the Queensland Government Station at South Johnstone. But compared with what is done elsewhere, these appear small efforts indeed. For example, some millions have been raised in the West Indies, and more still in Java, where, it is said, 20,000 or more are grown right to maturity each year as a regular practice. Even in such a small place as Fiji, 1000 to 2000 a year are regularly raised.

Yet seedling varieties are highly favoured in Australia, as elsewhere, many of our most prominent canes (D1135, M1900 Seedling, Innes 131, B208, etc.) having been foreign seedlings selected from the large numbers imported from time to time.

It would therefore seem high time that our serious attention was turned towards seedling raising. It would even seem a reasonable course to discontinue importations of foreign canes for the time being, in order to give our undivided attention to this other means of obtaining new varieties. It is further claimed that seedling raising, properly exploited, should give superior results, and thus obviate the need for foreign importations entirely.

For, there is no inherent difference between seedlings artificially raised and varieties occurring naturally. All the New Guinea canes (Badila, Goru, Mahona, etc.), for example, have originated, it is said, [e.g. Muir (8); Deerr (3)] as self-sown seedlings, which have then been selected for further propagation by the New Guinea natives, according to their own tastes. From the New Guinea canes we now possess, we may expect to obtain a series of seedlings of, ultimately, higher merit probably than would be provided by further collections from New Guinea. For, instead of allowing the Papuans to make the original selection of desirable varieties on their own primitive basis, we would do it strictly according to our commercial requirements. And this would apply to the selection of parent varieties as well as to that of the seedlings.

When to these considerations is added the fact that varieties will be thus obtained without further risk of introducing diseases, the case for discontinuing importations becomes indeed a strong one.

It may be objected that a wide range of varieties is required from which to select suitable seed parents for the seedlings, and that fresh importations will be required on that account. But it has been found best in practice to use as parents only the few varieties considered of highest promise. Such wide variation occurs amongst seedlings, especially when the crossing of two varieties is resorted to, that, if several hundred seedlings be raised from a single arrow, all will usually be different varieties. It therefore often becomes desirable to raise thousands of seedlings from a single pair of parents. Thus, our present small group of standard varieties alone should form a sufficient basis as parents. To these may be added, as desired, any of the other numerous varieties on trial. Further, if some special foreign cane should become particularly desirable for this purpose, some such system of quarantine as proposed above, would also provide means for its introduction.

A paper will shortly be prepared by The C.S.R. Company's Agriculturist on seedling raising and variety testing, detailing the efficient system used for the purpose in Fiji. This will afford further infor-

mation on the subject of seed parents. It will also show that the raising of the seedlings is a comparatively simple matter, now that the conditions required for germinating the seed and growing the young seedlings are understood. And that the "conspicuous" seedlings selected in the second or third year, amounting to perhaps 5 or 10 varieties from each 1000 seedlings raised, have proved in our experience, to be just as likely as imported varieties, to prove useful canes. A very high proportion of imported canes have failed in Australia and Fiji owing to lack of resistance to some disease. Even most of those coming with the highest reputations have quickly succumbed, usually to a disease not prevalent in their country of origin. Thus it is to be expected that at least as high a proportion of the "conspicuous" seedlings as of imported varieties would succeed on the commercial scale. Production of the former may be a little more laborious and costly than importation and raising stocks of the latter without proper safeguards. But it would be far otherwise when reasonable safeguards against diseases are observed.

VARIETY TESTING.

The real difficulties arise, not in raising the seedlings, but in testing them, especially in recognising and selecting the really superior varieties from amongst those picked out as "conspicuous." Exactly the same difficulties, however, arise in testing imported varieties. After sufficient healthy stocks of the latter have been raised, the same methods apply to both alike. This is the part, more than any other, that calls for high technical skill, wide experience, and sound judgment, in order that due weight may be allotted, no more and no less, to each of the various characters which determine the value of a variety for a particular set of conditions.

To commence with, each particular locality has its own peculiar set of conditions to cater for, and may require a different variety specially adapted to them. The different standard varieties now grown in different districts show this.

Next, not only must tonnage and sweetness of crop be considered, but also every character which influences the cost of cultivation, harvesting, and transport, or affects the milling qualities; the aim, of

course, being to obtain a cane which would prove more profitable to cultivate than the standard varieties of the locality concerned. These qualities need to be considered, too, in both plant and ratoon crops, in various seasons, good and bad, and on different classes of soil, as it is only by these means that the all-important characters of reliability, hardiness, and ratooning capacity may be determined. As each crop of cane takes from one to two years to develop, these characters cannot well be determined in any variety in less than 10 years.

The disease resistance of each variety needs to be determined separately for each individual disease prevalent in the locality concerned. Only moderately high resistance will be required against such diseases as Mosaic and Fiji disease which are controllable by other means. But against such diseases as true Rust and Root fungus disease, the very highest resistance, approximating to immunity must be looked for, until such time as other effective means of control are discovered. Similarly the degree of susceptibility which may be tolerated will vary inversely with the prevalence of the particular disease in the locality.

The methods of determining all these qualities will be detailed in the paper mentioned above. As the main object is to determine whether each new variety is or is not superior to the standard variety in use, the latter figures prominently in every trial and direct comparison of each is made with it. "Conspicuous" varieties (whether imported or seedlings) are first picked out by means of "preliminary" trials. Then the relative merits of these are determined by means of the more accurate "plot" trials. In these, elaborate precautions to secure even conditions have been found necessary, in order to ensure that strictly impartial comparisons may be made. Unavoidable variations in fertility are allowed for by using small plots arranged chess-board pattern and having a number of plots of each variety. As one variety will frequently grow at the expense of another alongside it, robbing it and thus invalidating the results, "inner" plots only are used in the comparisons, a fringe of guard cane being left surrounding each plot. How essential these and many similar precautions are, if accurate comparisons

be desired, will be amply demonstrated. Similarly, comparisons made of varieties as single stools or in one or two rows will be shown to be not only valueless but frequently most misleading.

After a variety has compared more than favourably with the standard variety, in a number of such plot trials, in plant and ratoon crops, on different representative classes of land, and in several different seasons, it is regarded as fit for trial on the commercial scale, gradually to replace the standard variety. Not until then is it considered fit for distribution to the farmers. The final judgment will, of course, depend on its performance on a large scale.

Thus variety testing should clearly be the function of the trained experimentalist. The prevailing custom of distributing varieties amongst the farmers for trial has, at best, afforded but a haphazard means of comparing varieties, which as already explained, have been selected mainly for their resistance to diseases. And owing to the great prevalence of diseases resulting from lack of other control measures directed against them, an unreasonably high standard of disease resistance in the varieties has been looked for. With his limited facilities, too, the farmer has had to rely mainly on a variety's physical appearance, and determinations of weight and quality have been usually lacking.

Further, how can a farmer, distracted by the multitude of other interests and worries attendant on running a farm, be expected to devote the close attention and thought required to weigh up all the factors indicated, in order to give considered judgment on a number of varieties he holds on trial? The fact is that it is the rarest occurrence to find that a farmer has planted his varieties in a manner which permits fair comparisons to be made. Frequently their trials include no standard variety for comparison, or land of even fertility is not selected, nor are plots duplicated, or the canes are planted in single rows instead of in plots, or the plots of different varieties are planted at different times. Almost invariably their comparisons are found to be invalidated by one or more drawbacks of this nature.

Farmers also incur considerable losses of crop, by planting unduly large areas with varieties of doubtful value. By the method of variety testing thus suggested, it is claimed that more reliable comparisons will be secured, while using a small fraction only of the areas at present occupied for this purpose. This will leave the bulk of these areas for cropping with the most approved standard variety, in the usual manner. The gains thus secured should alone more than pay for all the services of the experimental staff required.

But the chief objection of all to distributing varieties to farmers for trial, is on account of diseases. Even when they obtain and plant solely cuttings free from disease (and this has been far from being the usual case), a number of varieties will still constitute a menace to the farm on which they are planted. For it is common experience that diseases are far more prevalent in variety blocks than elsewhere. It has frequently been observed that even a standard variety proves far more liable to infection in variety trials, than it does in ordinary large areas by itself.

This peculiar phenomenon may be explained as follows:—Wherever a number of varieties are grown together, all will not be equally resistant to the diseases of the neighbourhood, but one will prove more susceptible to one disease, another to another and so on. Supposing that the infective principle of any disease at first reaches all the canes equally, odd stools of the most susceptible variety would contract the disease, while the rest still remain free. A new centre for propagating the infective principle is thus established in the midst of the varieties. Further stools of the susceptible variety also soon become infected. So that the whole block soon becomes subjected to heavy and frequent doses of the infective principle from this source. Under such conditions, a resistant variety may become infected in a large proportion of the stools, whereas infected stools may be comparatively rare in the same variety under ordinary field conditions.

Whether this be accepted as a correct explanation or not, the fact remains that variety blocks are particularly liable to propagate diseases. Abundant evidence of it is to be found on all sides. It constitutes a grave source of danger to experiment stations, or to

anybody who grows a number of varieties close together for any purpose. This is particularly so with large institutions which import numbers of varieties, and from which, after a period of propagation and testing, the varieties are again distributed. Such institutions have to contend not only with diseases which have already become prevalent in their own locality, but also with any others that may be introduced along with their imported varieties. They then have to shoulder the responsibility of risking the distribution of all these diseases along with the varieties they distribute, whenever, as so frequently happens, a disease is present in an early stage, or other not easily recognisable form.

It is experiences of this nature that have prompted large experiment stations almost throughout the world, to conduct their operations with varieties under the close supervision of competent plant pathologists. And numerous instances illustrating these contentions have been traced in the C.S.R. Co.'s operations with varieties in Fiji and Australia in the past. In fact, this is what has now decided them to make the radical changes here suggested in their own operations, and to propose the adoption of similar measures in Australia generally.

What is proposed will, of course, be entirely dependent for its success upon the co-operation of all concerned. For anyone may readily nullify any efforts made towards bringing a disease under control, especially such a one as Gumming, merely by re-introducing that disease to the locality in a few cane plants. The attention of the whole sugar-growing community is therefore invited to these proposals. First, that of the Queensland Bureau of Sugar Experiment Stations is invited, their variety operations being on the most extensive scale of all. In these they, too, evidently experience the kind of troubles with diseases indicated, the presence of diseases at the Stations being mentioned in many of their published reports. And evidently the precautions they take are not always sufficient to ensure that no diseased plants are distributed with their varieties. This was found when 6 cuttings each of 17 varieties from the Bundaberg Station were received at Broadwater mill in November, 1921. As inspection on arrival failed to reveal any disease, they were carefully planted and tended. How-

ever, it was found when growth commenced that all plants of one variety (N.G.94) were affected with Gumming, while those of another (Shahjahanpur No. 10) all had Mosaic.

Next, the farmers who obtain new varieties from a distance are warned. The common practice of obtaining varieties privately from other farmers is perhaps even more dangerous than procuring them from the Stations, because the precautions taken by the latter would be lacking with the former.

Finally, dairy farmers and others plant small areas of sugar cane for stock feed or other purposes. It being merely a small sideline, they have neither the interest nor the knowledge to bother about diseases. They often cultivate carelessly, and use the nearest available cane for seed purposes, irrespective of its condition. That many such blocks have been found badly diseased is therefore not surprising. Whenever these blocks are situated in the vicinity of proper cane areas, they constitute a grave menace to the cane farmers, and some means for dealing with them is required.

While diseases are being constantly disseminated far and wide by all of the means described, any individual efforts to control them, such as those now being made at the C.S.R. Co.'s Broadwater Mill, are rendered futile.

PART III.

4. APPLICATION OF PROPOSED MEASURES TO FARM PRACTICE.

An outline of what is being done at certain of the C.S.R. Co.'s mills will serve to indicate how it is proposed to apply the measures suggested to ordinary field practice.

The chief investigations on these matters have been carried out at the main nursery, Rarawai mill, Fiji, largely forming the basis of the work elsewhere. General pathological surveys of the cane areas of Australian mills were made periodically between 1910 and 1915 inclusive. Annual notes on the prevalence of and losses caused by diseases, their relation to varieties and so forth have also been furnished by the mill staffs.

Then in 1919, a laboratory was fitted up at Broadwater for the investigation of diseases, particularly Leaf Scald, which was found to be an infectious bacterial disease, controllable by measures already indicated. The following year the experimental staff was increased to four, in order also to undertake the control of the four important diseases, Leaf Scald, Gumming, Mosaic, and Fiji disease, as well as trials with varieties and manuring.

Seedling raising also is now to be undertaken, both at Macknade and at Broadwater mills. At the former mill, a small nursery for testing varieties, manuring, etc., has been in operation for many years.

Disease control work was also commenced in 1922 at Harwood mill, where Fiji disease is the main source of loss.

Extension of work on these lines is necessarily slow, chiefly owing to difficulties of personnel, an essential qualification for it being an intimate knowledge of the local diseases, varieties, and conditions generally. It will be gradually undertaken at other mills as a suitably trained staff becomes available. But there is ample scope for others besides the C.S.R. Co. to take up work on similar lines. We will gladly co-operate in any practicable manner with those who may decide to do so.

The procedure at Broadwater is as follows:—

Every farm is visited prior to each planting season, and the cane to be used for seed purposes is

examined for the presence of diseases and its suitability generally. At the same time, the symptoms by which each disease may be detected, especially in its early stages, are explained to the farmer. Varieties, selection of suitable seed cane and control of diseases generally are discussed with him: also in some cases manuring, drainage, and other questions, as they concern each particular farm. The farms are also visited at other periods, as opportunity offers. At each visit, notes are recorded in field plan books, which thus show the condition of each individual field, its area, variety, date of planting, source of seed cane, kind and amount of diseases present, manurial treatments, and so forth. The farmer's proposed planting programme, and whether plants are to be supplied to or obtained from other farmers, are also noted. Later, the effects of the procedure followed by each farmer in planting are similarly noted.

These records serve many purposes. Any farmer who lacks suitable seed cane for his requirements can readily be informed of the source from which it may be most conveniently obtained, of the condition and suitability of that which he proposes to obtain, and so forth. The records of one season are of such value the next, that the work diminishes while the control increases each successive year, a continuous history of each individual field being thus provided. The extent of the spreading of each disease and the success in controlling it are accurately determined. A detailed estimate may be made of the losses caused by each. Many valuable indications are obtained of the manner in which the diseases spread, and the distances over which infection is normally carried. And a good basis is provided for investigating any obscure outbreaks which occur, many of these having thus been traced their probable source. The relative powers of resistance of varieties to diseases are observed throughout the district, it being known in each case whether the disease arose from infected seed cane or by secondary infection. Opportunity is also afforded for comparing varieties on the basis of mill weights and analyses, as each case is known where valid comparisons may be made. This district is exceptionally favourable for all such observations, owing to the large number of varieties grown on a field scale (N.G.16, Mahona, Malabar, D1135, Innes 131, Badila, 1900 Seedling, H.Q.5, and

others). For the same reason, it may be added, it particularly lends itself to the dissemination of diseases, the control of which becomes correspondingly difficult. Generally speaking, those mill districts in which only one or two standard varieties are grown, are the most free from diseases and are the ones in which the diseases may be most readily controlled.

Plot trials, as described earlier, have also been laid out on a number of farms for the comparison of varieties. These are tended by the farmers concerned in the ordinary course of their farm work. But, at harvesting, the canes of each plot are weighed with a spring balance and tripod on the plot, after which each inner plot row is accurately measured for determination of areas. Owing to transport of cane by punts, two separate stalk samples, each comprising a whole stool, are taken for analysis from each plot. Where tramline transport is in vogue, truck samples are to be preferred for this purpose. Similar trials on manuring and other questions are also in progress.

Only the prominent varieties can, of course, be tested in this manner. Some 80 odd varieties altogether, mainly introduced by farmers prior to 1919, are now on trial. Preliminary selection trails of these are planted in plots of 3 to 4 rows, one half chain long, and 1 to 3 plots of each variety. For this purpose, a fresh block of land of about 2 acres is leased each year from a farmer, in a specially selected locality. Owing to the special liability to disease of such blocks, as already explained, and to the present prevalence of diseases in the district, the strictest precautions are now necessary to keep these blocks free from disease. But this portion should gradually ease in proportion as diseases are brought under control. But by careful seed selection, and choice of disease-free localities, known diseases have so far been avoided, except in one instance. In this case, the varieties from Bundaberg Experiment Station already mentioned were planted at a corner of the 1921 block. Although Mosaic spread from the plants of Shahjahanpur No. 10 into some 20 or 30 neighbouring stools, prompt destruction of the diseased plants as they were discovered, effectively served for its eradication. But it was quite otherwise with Gumming disease. Although the affected plants were destroyed 3 months after being planted, and as soon as symptoms could be detected, later examination

showed that the disease had already spread to neighbouring canes. Most of the affected stools were in the next row alongside the blank spaces from which the original plants had been removed. But one affected stool was found 50 feet distant, and others at shorter distances. As the neighbourhood had been free from Gumming for many years previously, and knowing the virulent nature of the disease in other parts of the district, drastic measures were adopted to stamp it out, nearly an acre of the trial block being ploughed out and the plants destroyed. Whether this course has saved the remainder of the block and adjoining fields from infection remains to be seen, as experiences elsewhere indicate that further symptoms may not develop until next winter, or even later.

In small blocks adjoining the mill, experiments with diseased canes are laid out, both for research and for demonstration purposes. They serve well for demonstrating the nature of the diseases and methods of detecting them, and larger or smaller groups of farmers are frequently shown round for this purpose. By these means they have been shown, amongst other things, comparisons between the use of healthy and infected cuttings for planting; and that the most lightly infected plants may be just as dangerous as badly diseased ones. The dangers of knife-infection, the occurrence of secondary infection by natural means and by means of artificial inoculations, and many similar features have also been demonstrated. The teachers at two local State schools, with our assistance, also established tiny demonstration plots of this kind, and these proved very useful. For obvious reasons, such plots need to be isolated from ordinary cane fields by one quarter of a mile or so, and no disease not already present in the neighbourhood should be introduced into them.

The guiding principle throughout the work is to provide the farmers with useful information, and to show them how the diseases may be controlled and how their crops may be otherwise improved. They alone are competent to deal with their own crops. Diseases cannot be removed for them.

Experiments have recently been made which show that seedling raising is a thoroughly practicable proposition in these southern latitudes, by raising the

canes from arrows sent from tropical mills. Two minor difficulties are involved. First, whatever is done towards securing cross-fertilised seed, suitable seed parents and so forth, will be in different hands to those who raise and test the seedlings. Second, there may be some risk of diseases being carried along with the seed. This risk, however, appears extremely slight compared to that involved when cuttings are forwarded, although the question seems scarcely to have been investigated with sugar cane. For, a small proportion only of the diseases of other plants are liable to be carried along with their seed, especially in the case of plants usually propagated by cuttings or other vegetative means. Further, cane seedlings are naturally so delicate that infected seed, if any should be sown, would usually fail to grow. The close supervision under which they will be raised would therefore seem a sufficient guarantee against this risk.

ESTIMATES OF LOSSES.

As indicated above, the data recorded in the field plan books form a far better basis for a detailed estimate of the losses due to each disease than has usually been available to the mill staffs for this purpose. Owing to the complexity of the questions involved and to the large amount of work entailed, estimates of losses have rarely been made. And those made have usually included little more than the most obvious losses, such as where whole fields have proved a total loss. The following summary of the losses suffered by the Broadwater crops of 1920 and 1921, carefully compiled on the basis indicated, should therefore be of interest. However, even these estimates must be regarded as a considerable understatement of the true position. For, besides being made on a conservative basis throughout, it was not possible to make allowance in them for such an important factor as the use of otherwise inferior varieties, owing to their resistance to certain diseases. Malabar, for example, is here largely replacing Mahona, 1900 Seedling and other varieties superior to it in sugar content and at least its equal in yielding capacity when healthy, because of its greater resistance to Gumming. The estimates also take no account of loss of quality, being made purely on a

tonnage basis. And they deal solely with the four diseases named, losses from other causes having been carefully excluded.

SUMMARY OF ESTIMATED LOSSES (TONS CANE) IN THE BROADWATER MILL DISTRICT, RICHMOND RIVER.

	In 1920 crop of 59,000 tons cane crushed.	In 1921 crop of 70,600 tons cane crushed.
From Gumming Disease	2,907	1,688
From Leaf Scald Disease	940	2,017
From Fiji Disease	300	220
From Mosaic Disease	1,233	2,586
From Total of 4 Diseases	5,380--9.1%	6,511--9.2%

These losses, amounting to over 9 per cent. of the total cane harvested, may be regarded as representing approximately normal average losses for this district, the two seasons concerned being by no means abnormal ones as regards losses from disease. Losses have doubtless been much higher than this in many mill districts in times of severe epidemics, while they would be much less in the districts least subject to diseases. It would probably be a conservative estimate to assume a loss of 5 per cent. from diseases in sugar cane throughout Australia. What this means on an annual crop of about 2,000,000 tons, worth say £2 per ton may readily be gauged.

RESULTS OF CONTROL MEASURES.

The seed selection campaign commenced in 1920 did not influence the losses indicated above. The cane being nearly all harvested at two years old, the first results should be apparent in the plant cane harvested in 1922, while no ratoon crop will be influenced before 1924. It is anticipated that considerable improvement in regard to Mosaic and Fiji disease will be shown by the plant cane, when the data for 1922 are compiled, and there is every prospect of these two diseases being rapidly and completely controlled. But much less success has attended the work with Gumming and Leaf Scald, many farmers at first refusing guidance. They could not credit that fields of cane in which no single diseased stool could be found, were nevertheless probably infected, and were to be regarded as unsafe for seed purposes. Many, therefore, used cane of this

class in 1920 and 1921 rather than go further afield for cane considered safe for use as plants. This course led to such disastrous results, however, that all were fully convinced and accepted guidance in 1922. Thus, control of these two diseases should be regarded as having only just commenced, and considerable results need not be looked for for several years yet.

The trouble arose through the great liability of Gumming and Leaf Scald to be present in cane in an unrecognisable condition. It was found necessary to classify each field for seed purposes as either (1) safe, (2) unsafe, or (3) diseased. In doing this the discovery of even one single diseased stool served to condemn the whole field as "diseased"; while proximity (up to a quarter mile distant) to another diseased field, or being raised from doubtful seed and other similar considerations served to class the field as "unsafe." That such drastic classification as this was justified, was amply proved by the results obtained.

Taking, for example, the favourite variety Mahona, to which greatest attention was given in this respect in 1921, twenty-three farmers used "safe" seed cane, with which 98 acres were planted in all. The resulting crops were all apparently healthy at first and a large proportion still remains so. Secondary infection has developed in many cases where it was planted in an infected locality. In another case where Gumming has developed, there are strong grounds for suspecting knife infection.

Twenty-eight farmers planted 120 acres in all with "unsafe" seed cane. Of these, 10 were apparently healthy at first, but 17 straight away developed Leaf Scald and one Gumming. Of the 10 apparently healthy at first, Leaf Scald has since developed in the case of 3, not only in the new field planted, but also in the ratoons which have grown where the seed cane was cut.

Forty-six farmers planted 214 acres with seed cane classified as "diseased" (104 acres with Leaf Scald, 88 with Gumming, and 22 with both). In every instance the disease noted developed straight away, although in no case had the disease been conspicuous in the seed cane. Usually a few inconspicuous leaf streaks (those characteristic of Gumming or of Leaf Scald as the case might be), in one or a few stalks,

were the only discoverable evidence of the disease, and in many cases the farmer concerned carefully avoided the part of the field in which these were found. It was the great damage caused by Gumming which resulted in some of these crops, a few of which may not even be worth harvesting, that most impressed the farmers with the soundness of the classification used.

The excessive wet weather of 1921 favoured an unusually rapid spreading of Gumming by secondary infection, especially in areas where drainage was deficient. The disease is thus approaching epidemic proportions, having now gained a foothold in nearly all parts of the district, whereas it was previously confined to a few well defined areas. Losses from it will show a big increase in 1922, and probably a still further increase in 1923. As a result its control will now be a matter of great difficulty, and will depend mainly on the use of resistant varieties (especially Malabar), improved drainage, and the advent of dry seasons; to control it by ordinary methods of seed selection and field sanitation alone seems impracticable now that it is so widespread. But whole-hearted adoption of such means by the farmers concerned in 1920, would at least have prevented much of its recent rapid dissemination, and might possibly also have served to keep it under control, in spite of the weather favouring its spread.

The chief problem with Leaf Scald was to endeavour to control it while, at the same time, retaining the highly suspectible Mahona in general use. This variety, apart from diseases, stands out as apparently the most profitable cane of all to grow in this district. However, the rapid spread of Gumming described above, especially in the previously "safe" Mahona areas, has destroyed the prospects of achieving this object. Now that the use of this variety is being discontinued, the control of Leaf Scald should offer no greater difficulties than that of Fiji disease or Mosaic. The ultimate complete eradication of both Gumming and Leaf Scald will now be hoped for, in order subsequently to make possible the re-introduction of a fresh healthy stock of Mahona to the district.

The above description of the procedure adopted at Broadwater, the examples given of the problems encountered and the means used for their solution,

should be sufficient indication of the kind of measures which will be required in each district. It may, however, be pointed out that much of the information gained proves of more or less general application. Full correlation of the work of all the various centres will, therefore, serve enormously to reduce the task of controlling diseases generally. At the present time, it seems desirable that in addition to mantaining one or more centres where detailed investigations are made, a trained experimentalist should be stationed at each mill. But owing to the lack of a suitably trained staff this is not immediately practicable, and it may later be found to be more than is necessary for disease control work alone. However, even when diseases have been brought practically under control, there would still remain unlimited scope for extending the work of such officers in other directions.

SUMMARY.

Sugar cane diseases have been freely imported into and widely disseminated in Australia along with cane plants. Several important ones, which until recently were not recorded elsewhere, thus came from New Guinea.

This has been due to the lack of proper safeguards against diseases, which are needed whenever cane plants are transported from one place to another.

Resistant varieties have provided the main means used for the control of these diseases.

This has led to the importation and distribution of both varieties and diseases on an unusually large scale, with disastrous results.

Although a large proportion of the varieties have been discarded, many diseases came to stay, defying eradication. The latter are still widely distributed.

The popular conception that varieties deteriorate or "run out" through senility is not tenable. "Running out" is due to diseases, and is preventible. Desirable varieties which "run out" may be reverted to after the disease responsible has been brought under control.

For discussion of control measures, the diseases have been arbitrarily divided into three types.

All three types are liable to dissemination along with cane plants.

Type 1 comprises our most important diseases (Gumming, Leaf-Scald, Leaf-Stripe, Fiji Disease, and Mosaic). All are caused by strict parasites, which do not usually live and multiply in the soil or otherwise apart from living cane. They are highly infectious. Although incurable, they are preventible by seed selection, eradication of diseased stools, and measures of field sanitation generally. The use of resistant varieties is a valuable adjunct to these measures.

Type 2 comprises diseases caused by weaker facultative parasites (Red Rot, Root fungus disease, Sclerotial diseases, etc.). Infection from the soil takes place, as well as that from diseased to healthy plants. Control measures include the use of resistant varieties, reducing infection from the soil by agricultural methods, and seed selection.

Type 3 comprises many of the so-called "Rust" spots and other markings of the leaves. Control mea-

sures are not usually required, beyond the use of resistant varieties in certain cases.

Ability to differentiate between the various so-called "Rust" markings of the leaves is highly important in practice because, in addition to those of type 3, certain leaf markings are caused by the diseases of types 1 and 2. These, too, afford the most valuable means available for the detection of our more important diseases.

Seed selection depends for its success, first on ability to distinguish each disease in its various phases, and especially in its very early stages; next on a knowledge of its nature and the manner in which it spreads.

A plan is outlined, proposing severe limitations on the importation of varieties, and their distribution within Australia.

Resistant varieties must be obtained for combating diseases.

New and improved varieties are needed for increasing crop yields.

On the other hand, in distributing varieties, it is usually impossible to guarantee the freedom from disease of the cane plants selected at the forwarding end.

Similarly, no precautions, short of a strict quarantine, are to be relied upon to hold diseases in check at the receiving end.

Seedling raising as an alternative means of obtaining new varieties, to replace importation, is therefore suggested as the basis of this plan.

The faulty seed selection, which renders cane plants liable to carry diseases, may arise from:—

(1) Carelessness or ignorance.

(2) Our inability to recognise some obscure diseases.

(3) The capacity of certain diseases to occur in cane in a latent unrecognisable condition for long periods.

The difficulties in carrying out an effective quarantine arise from similar factors, combined with the ability of certain diseases to spread rapidly, and the liability of infection to be carried considerable distances by insect, human, and other agencies.

Methods of quarantine are discussed, of which the essentials are:—

(1) Proper isolation, which may be secured in various ways.

(2) Dealing with few plants of only one to three varieties at a time.

(3) Frequent inspections, to ensure prompt eradication of diseased plants during growth in quarantine.

(4) Two years, without any disease symptoms appearing, is suggested as the minimum safe quarantine period.

No quarantine system will eliminate risks completely. The risks incurred will be part of the price to be paid for a variety of outstanding promise.

Reasons are advanced for regarding seedling raising as generally preferable to importation as a means of obtaining new varieties, with the additional advantage that no diseases will be imported.

The raising of seedlings offers no considerable difficulties.

The chief difficulties, both with seedlings and with imported canes, arise in the selection of the few superior varieties from the multitude.

Improvements in the methods of testing varieties are suggested. These aim both at securing more reliable comparisons, and at limiting the dissemination of diseases.

The changes proposed also involve a longer trial period before distribution to farmers. Thus, only the few really superior canes would be distributed, in place of numbers of half tested varieties as at present.

Farmers now devote unnecessarily large areas to varieties on trial. They should derive great gains from cropping these areas with the most approved standard variety, instead of with varieties of doubtful value.

The growing of a number of varieties close together greatly favours spreading of diseases.

In variety work it is therefore necessary to take special precautions against diseases, beyond what farmers are usually in a position to carry out.

The necessity for general co-operation in all matters concerning the control of diseases and varieties are emphasised.

The futility of individual efforts at disease control under present circumstances is pointed out.

In order to illustrate the application of the proposed measures to ordinary farm practice, the procedure in the Richmond River district is outlined.

All the farms are periodically visited, when farmers are assisted in their selection of seed cane, and supplied with information on all matters of diseases and varieties.

A history of each individual field is recorded in field plan books, which show area, variety, age, source of seed cane, diseases present, etc.

These records form the basis of all the control work, and of extensive field observations.

Variety and other trials are tended by the farmers, but are planted, weighed, and controlled generally by the experimental staff.

Seedling raising is also to be undertaken.

Detailed estimates were compiled, showing that 9 per cent. of the crop was lost through Gumming, Leaf-Scald, Mosaic and Fiji diseases, in 1920 and 1921.

These losses were not influenced by the seed selection commenced in 1920. Crops planted before 1920 will continue to be harvested for several years to come.

Control of Mosaic and Fiji disease is proving successful, but difficulties arose with Gumming and Leaf-Scald.

Farmers refused to believe that cane was infected when no symptoms of disease could be detected.

Fields are classified for seed purposes as (1) safe, (2) unsafe, (3) diseased. It is shown that the results from the planting of each type fully justified this classification.

Rapid spread of Gumming took place by secondary infection in the excessively wet year of 1921. Its control will now be difficult.

Mahona is being discarded owing to being severely attacked by both Gumming and Leaf-Scald. This should make control of Leaf-Scald a simple matter.

It is suggested that a trained experimentalist should be stationed at each mill for variety testing, disease control and similar matters.

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